

SECTION 346 PORTLAND CEMENT CONCRETE

346-1 Description.

Use concrete composed of a mixture of portland cement, aggregate, water, and, where specified, admixtures and pozzolan. Deliver the portland cement concrete to the site of placement in a freshly mixed, unhardened state.

Meet the production and quality control of concrete provisions of this Section and the Florida Department of Transportation Standard Operating Procedures.

346-2 Materials.

346-2.1 General: Meet the following requirements:

Coarse Aggregate	Section 901
Fine Aggregate*	Section 902
Portland Cement.....	Section 921
Water.....	Section 923
Admixtures.....	Section 924
Fly Ash, Slag** and Microsilica (Pozzolanic Materials).....	Section 929

*The Engineer will allow only silica sand except as provided in 902-5.2.3.

**The Engineer will allow only granulated blast furnace slag.

Use the materials containing no hardened lumps, crusts or frozen matter, and that are not contaminated with dissimilar material.

346-2.2 Types of Cement: Unless a specific type of cement is designated elsewhere, use Type I, Type IP, Type IS, Type IP(MS), Type II, or Type III cement in all classes of concrete.

Use only the types of cements designated for each environmental condition in structural concrete.

TABLE 1			
BRIDGE SUPERSTRUCTURES			
Component	Slightly Aggressive Environment	Moderately Aggressive Environment	Extremely Aggressive Environment
Precast Superstructure and Prestressed Elements	Type I, Type II, Type III, Type IP, Type IS, or Type IP (MS)	Type I, Type II, and Type III all with Fly Ash or Slag; Type IP, Type IS, or Type IP(MS)	Type II with Fly Ash or Type II with Slag
C.I.P. Superstructure Slabs and Barriers	Type I, Type II, Type IP, Type IS, or Type IP(MS)	Type I with Fly Ash or Slag, Type II, Type IP, Type IS, or Type IP(MS)	Type II with Fly Ash or Type II with Slag
BRIDGE SUBSTRUCTURE, DRAINAGE STRUCTURES AND OTHER STRUCTURES			
Component	Slightly Aggressive Environment	Moderately Aggressive Environment	Extremely Aggressive Environment
All Structure Components	Type I, Type II, Type III, Type IP, Type IS, or Type IP (MS)	Type I with Fly Ash or Slag, Type II, Type IP, Type IP(MS), or Type IS	Type II with Fly Ash or Type II with Slag

346-2.3 Use of Fly Ash, Slag, Microsilica, and Other Pozzolanic Materials: The Contractor may use fly ash, slag, microsilica and other pozzolanic materials as a cement replacement in all classes of concrete (when Type I, Type II, or Type III cement is used) with the following limitations:

(1) When fly ash, slag or microsilica is used as a cement replacement, use it on a pound per pound [kilogram per kilogram] basis. Calculate cement replacement as shown in the example.

Example - Assume a total cementitious content of 752 pounds [341 kg]. Calculate the required microsilica for a 7.6% replacement as $752 \text{ by } .076 = 57 \text{ pounds}$ [341 by .076 = 26 kg]. Calculate the required fly ash for a 20% replacement as $752 \text{ by } 0.20 = 151 \text{ pounds}$ [341 by 0.20 = 68 kg]. Cement required is 544 pounds [247 kg].

(2) Ensure that the quantity of cementitious material replaced with fly ash in mass concrete is greater than 18% and less than 50% by weight of the total cementitious content. The minimum cementitious content for each class of concrete is shown in the Master Proportion Table (Table 3).

(3) Ensure that the quantity of cementitious material replaced with fly ash in drilled shaft concrete is $35 \pm 2\%$ by weight of the total cementitious content.

(4) For all other concrete uses not covered in (2) and (3) above, ensure that the quantity of cementitious material replaced with fly ash is greater than 18% and less than 22% by weight of the total cementitious content.

(5) Ensure that the pozzolan constituent of Type IP(MS) is in the range of 15 to 40% by weight of the portland-pozzolan cementitious material.

(6) Obtain the Engineer's approval to use pozzolanic materials other than Class F fly ash.

(7) Ensure that the quantity of cementitious material replaced with slag in drilled shaft concrete is $60 \pm 2\%$ by weight of the total cementitious content.

(8) For all other concrete uses not covered in (7) above, ensure that the quantity of cementitious material replaced with slag is not less than 25% or greater than 70% of the total cementitious content when used in Slightly and Moderately Aggressive environments, and not less than 50% or greater than 70% of the total cementitious content when used in Extremely Aggressive environments. When used in combination with microsilica, ensure that the slag does not replace less than 50% or more than 55% of the total cementitious content.

(9) Ensure that the quantity of cementitious material replaced with microsilica is not less than 7% or greater than 9%. Use high range water reducing admixtures in concrete mixes incorporating microsilica.

346-2.4 Coarse Aggregate Gradation: Produce all concrete using Size No. 57 or Size No. 67 coarse aggregate except as follows:

(1) With the Engineer's approval, the Contractor may use Size No. 8 or Size No. 89 either alone or blended with Size No. 57 or Size No. 67 for concrete construction that is heavily reinforced or for barrier wall or curb construction using slip forms.

(2) The Engineer may approve other gradations of aggregates. The Engineer will consider requests for approval of other gradations individually and will require the Contractor to submit sufficient statistical data to establish production quality and uniformity of the subject aggregates, and to establish the quality and uniformity of the resultant concrete. Furnish aggregate gradations sized larger than nominal maximum size of 1.5 inch [37.5 mm] as two components.

(3) Select the maximum coarse aggregate size so as not to violate the reinforcement spacing provisions given for reinforced concrete in the AASHTO Standard Specifications for Highway Bridges.

346-2.5 Admixture Requirements:

346-2.5.1 Chemical Admixtures: Use concrete containing a water-reducing admixture (Type A) or water-reducing and retarding admixture (Type D). Use a dosage rate that is generally in accordance with the manufacturer's recommended dosage rate. When necessary, adjust the dosage rate.

The Engineer may approve the use of other admixtures. The Engineer will require the Contractor to submit statistical evidence supporting successful laboratory and field trial mixes which demonstrate improved concrete quality or handling characteristics.

The Engineer will not allow chemical admixtures or additives containing calcium chloride (either in the raw materials or introduced during the manufacturing process) in reinforced concrete.

346-2.5.2 Air Entrainment Admixtures: Ensure that all concrete except counterweight concrete contains an air entraining admixture. Establish dosage rates by trial mixes, and adjust them to meet field conditions.

346-2.5.3 High Range Water Reducing Admixtures: Use high range water reducing admixtures in concrete mixes incorporating microsilica. The Contractor may propose the use of an approved High Range Water Reducer (HRWR) admixture, either Type F or Type G. In a proposal to use HRWR for precast items, include a list of precast items for which it is proposed. The Contractor may also propose the use of HRWR for cast-in-place concrete, except for concrete used in drilled shafts. In a proposal to use HRWR for cast-in-place items, include a detailed listing of the areas, locations, elements, etc. for which its use is proposed and the anticipated benefits to be derived from the use of HRWR in each instance.

Perform all testing for plastic concrete properties after the HRWR has been added to the concrete mix.

The Department will not consider Value Engineering credits or other price adjustments for proposals to utilize HRWR in order to reduce the specified minimum cementitious requirements for the various classes of concrete.

In a proposal to use HRWR in concrete, include the following:

A certification from the HRWR supplier that the HRWR admixture proposed meets the requirements of ASTM C 494, Type F or G. Ensure that the certificate states that the one year tests representing the admixture to be supplied have been performed by an independent laboratory approved by the Cement and Concrete Reference Laboratory (CCRL) and that the records of such tests will be furnished to the Department on request. Ensure that the certification also includes an additional statement from the HRWR supplier or an approved independent testing laboratory that the proposed HRWR admixture is compatible with all other admixtures to be included in the concrete design mix.

When a HRWR admixture is proposed for use in the design mix, propose a target slump value. Ensure that the target slump does not exceed 7 inches [180 mm]. Meet the other control requirements and ranges as specified herein.

Include with the confirming data all details of the design mix ingredients, all required certificates from the supplier and independent testing laboratory, and a certificate from the Witnessing Department Engineer. Ensure that the certificate states that the Contractor has demonstrated through production and placement of the required number of batches that concrete containing HRWR has been produced meeting all test requirements, that the HRWR concrete has been satisfactorily mixed in accordance with the Contractor's proposed methods and sequences, and that the concrete was acceptably placed, consolidated and cured.

Before the Engineer approves any design mix, demonstrate through production of at least three batches (3 yd³ [2.3 m³] minimum size each) of concrete containing the HRWR that the concrete plant can produce concrete consistently meeting specified slump, air content, and compressive strength requirements. Also demonstrate to the Witnessing Department Engineer that the concrete containing the HRWR admixture in accordance with the proposed design mixes can be placed, consolidated and finished under conditions existing for the proposed uses. Obtain the Engineer's approval before using HRWR concrete design mixes.

The Engineer may approve proposed HRWR mixes for concrete, centrally mixed at the placement site, without the production of demonstration batches providing you meet the requirements of 346-6.2, and:

(1) A previously approved HRWR mix of the same class has demonstrated satisfactory performance under the proposed job placing conditions with a minimum of 15 consecutive Department acceptance tests which met all plastic and hardened concrete test requirements.

(2) The cement and water reducing admixtures used in the proposed mix are the same materials from the same source used in the previously approved mix (Item (1) above), and the other materials and mix proportions are approved as similar by the Engineer.

Dispose of concrete produced for demonstration purposes at no expense to the Department. Subject to the Engineer's approval, the Contractor may incorporate this concrete into unreinforced concrete items.

Include with each design mix a description of methods, sequences, times and places that the HRWR will be introduced into the concrete mix for each proposed use. Adjust methods, sequences, times and places for introduction of the HRWR to suit the requirements for each proposed use and condition. The Contractor may transfer design mixes including a HRWR based on demonstrated ability of the mix to perform its intended function.

The Engineer will consider design mixes submitted for approval upon receiving certification from the Witnessing Department Engineer that the Contractor has demonstrated the ability to produce concrete containing a HRWR admixture in accordance with the proposed design mixes, meeting minimum strength requirements within specified ranges for slump and air, and which can be placed, consolidated and finished under conditions existing for the proposed uses. In addition, the Witnessing Department Engineer will include in the certification the test values of the slump, air and 28-day strength tests for all demonstration batches of concrete, and an evaluation and description of the Contractor's actual sequences, methods and time required for the placement and consolidation of each batch of concrete. Also include in the certification, the Witnessing Department Engineer's evaluation of the appearance, apparent consolidation and finish texture after form removal of each item cast.

Except for casting unreinforced concrete items as approved by the Engineer, do not produce or place demonstration concrete containing a HRWR admixture for payment under Contract pay items until design mixes containing the HRWR have been approved. To qualify for payment under Contract pay items, ensure that unreinforced demonstration concrete, cast with the approval of the Engineer, meets minimum strength and entrained air requirements contained in these Specifications, and that the slump is within 1.5 inch [40 mm] of the target slump proposed by the Contractor.

346-2.5.4 Corrosion Inhibitor Admixture: Ensure that concrete containing a corrosion inhibitor admixture also contains cementitious materials consisting of Type II cement and Class F fly ash. The Contractor may use ground granulated blast furnace slag in lieu of fly ash.

Ensure that concrete containing a corrosion inhibitor admixture also contains a water reducing retardant admixture (Type D). The Contractor may also need to use a high range water reducer Type F (or Type G) to provide the required workability and to normalize the setting time of concrete. Ensure that all admixtures are compatible with the corrosion inhibitor admixture.

346-2.6 Mixing Different Coarse Aggregates: The Engineer may allow the substitution of coarse aggregate of the same type from a different source in an approved concrete mix when the aggregate to be substituted is also from an approved source and has similar physical and chemical properties. If unsatisfactory results are obtained with the different source aggregate, return to the aggregate from the originally approved aggregate source of supply.

346-3 Classification, Strength, Slump, and Air Content.

346-3.1 General: The separate classifications of concrete covered by this Section are designated as Class I, Class II, Class III, Class IV, Class V, and Class VI. Strength, slump, and air content of each class are specified in the following (Table 2):

TABLE 2			
Class of Concrete	Specified Minimum Strength (28-day) (psi) [(MPa)]	Target Slump (inches) [(mm)](d)	Air Content Range (%)
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TABLE 2			
Class of Concrete	Specified Minimum Strength (28-day) (psi) [(MPa)]	Target Slump (inches) [(mm)](d)	Air Content Range (%)
I (Pavement) (b)	3,000 [21]	2 [50]	1 to 6
I (Special) (a)	3,000 [21]	3 [75]	1 to 6
II (a)	3,400 [23]	3 [75] (c)	1 to 6
II (Bridge Deck)	4,500 [31]	3 [75] (c)	1 to 6
III	5,000 [35]	3 [75] (c)	1 to 6
III (Seal)	3,000 [21]	8 [200]	1 to 6
IV	5,500 [38]	3 [75] (c)	1 to 6
IV (Drilled Shaft)	4,000 [28]	8 [200]	0 to 6
V (Special)	6,000 [41]	3 [75] (c) (e)	1 to 5
V	6,500 [45]	3 [75] (c)	1 to 5
VI	8,500 [59]	3 [75] (c)	1 to 5

(a) The Contractor may use concrete meeting the requirements of ASTM C 478 (4,000 psi) [ASTM C 478M (30 MPa)] in lieu of Class I or Class II concrete in precast items manufactured in plants which meet the Department's Standard Operating Procedures for Precast Drainage products. Apply the chloride content limits specified in 346-4.2 to all precast or cast-in-place box culverts.

(b) Ensure that consistency of the concrete is such that the edges of the pavement surface consistently meet the surface requirements in Section 350.

(c) The Engineer may allow higher target slump, not to exceed 7 inches [180 mm], when a high range water reducer is used.

(d) The Engineer may approve a reduction in the target slump for slipformed or prestressed elements.

(e) When the use of microsilica is required as a pozzolan in Class V (Special) concrete, ensure that the concrete does not exceed a permeability of 1,000 coulombs at 28-days when tested per AASHTO T 277. Submit 2, 4-inch [100 mm] diameter by 8 inch [200 mm] length cylindrical test specimens to the Engineer for permeability testing prior to mix design approval. The permeability of the concrete will be taken as the average of two tests. The Engineer may require permeability tests during production.

346-3.2 Drilled Shaft Concrete: When drilled shaft concrete is specified or required in the Contract Documents and is to be placed in any wet shaft, provide concrete in accordance with the following specified slump loss requirements. When concrete is placed in a dry excavation, do not test for slump loss, except where a temporary removable casing is required.

Ensure that drilled shaft concrete has a slump between 7 inches and 9 inches [180 mm and 230 mm] when placed and maintains a slump of 4 inches [100 mm] or more throughout the drilled shaft concrete elapsed time. Ensure that the slump loss is gradual as evidenced by slump loss tests described below. The concrete elapsed time is the sum of the mixing and transit time, the placement time and the time required for removal of any temporary casing that causes or could cause the concrete to flow into the space previously occupied by the temporary casing.

Provide slump loss tests before drilled shaft concrete operations begin, demonstrating that the drilled shaft concrete maintains a slump of at least 4 inches [100 mm] throughout the concrete elapsed time. Inform the Engineer at least 48 hours prior to performing such tests in order to allow arrangements to be made for a Department representative to witness the mixing and testing required. Perform slump loss testing of the drilled shaft mix using a laboratory acceptable to the Engineer. Use a laboratory that (1) has been inspected by the CCRL on a regular basis, with all deficiencies corrected, and under the supervision of a Specialty Engineer, or (2) meets all the requirements of ASTM C 1077.

Perform the following procedures for slump loss tests:

(1) Perform a test for time of setting of concrete mixtures by penetration resistance (FM 1-T 197).

(2) Prepare the mix for the slump loss test at a temperature consistent with the highest ambient and concrete temperatures expected during actual concrete placement. Obtain the Engineer's approval of the test temperature.

(3) Ensure that the mix is at least 3 yd³ [2.3 m³] and is mixed in a mixer truck.

(4) After initial mixing, determine the slump, concrete temperature, ambient temperature and air content. Ensure that the concrete properties are within the required specification limits. Initiate the time of setting test (FM 1-T 197) at this time.

(5) Mix the concrete intermittently for 30 seconds every five minutes at the mixing speed of the mixer.

(6) Determine slump, concrete temperature, ambient temperature and air content at 30 minute intervals until the slump is 2 inches [50 mm] or less. Remix the mix for one minute at the mixing speed of the mixer before these tests are run.

(7) Begin all elapsed times when water is initially introduced into the mix.

(8) Ensure that the concrete maintains a slump of at least 4 inches [100 mm] for the anticipated elapsed time.

(9) Obtain the Engineer's approval of slump loss test results in terms of elapsed time prior to concrete placements.

346-3.3 Mass Concrete: When mass concrete is designated in the Contract Documents, provide an analysis of the anticipated thermal developments in the mass concrete elements for all expected project temperature ranges using the proposed mix design, casting procedures, and materials. Additionally, describe the measures and procedures intended for use to maintain a temperature differential of 35°F [2°C] or less between the interior and exterior portions of the designated mass concrete elements during curing. Submit both the mass concrete mix design and the proposed plan to monitor and control the temperature differential concurrently to the Engineer for approval a minimum of ten working days prior to concrete placement. Provide temperature monitoring devices approved by the Engineer to record temperature development between the interior and exterior portions of the elements at points approved by the Engineer. Read the monitoring devices and record the readings at not greater than 6-hour intervals, as approved by the Engineer, beginning when casting is complete and continuing until the maximum temperature differential is reached and begins dropping. If monitoring indicates the 35°F [2°C] differential has been exceeded, take immediate action to retard further growth in the temperature differential and make the necessary revisions to the approved plan to maintain the 35°F [20°C] or less differential on any remaining placements. Obtain the Engineer's approval of revisions to the approved plan prior to implementation.

346-4 Composition of Concrete.

346-4.1 Master Proportion Table: Proportion the materials used to produce the various classes of concrete in accordance with the following (Table 3):

TABLE 3		
Class of Concrete	Minimum Total Cementitious Content lb/yd ³ [kg/m ³]	*Maximum Water Cement Ratio lb/lb [kg/kg]
I (Pavement)	508 [300]	0.50
I (Special)	508 [300]	0.50
II	564 [335]	0.49
II (Bridge Deck)	611 [365]	0.44
III	611 [365]	0.44
III (Seal)	611 [365]	0.52
IV	658 [390]	0.41

TABLE 3		
Class of Concrete	Minimum Total Cementitious Content lb/yd ³ [kg/m ³]	*Maximum Water Cement Ratio lb/lb [kg/kg]
IV (Drilled Shaft)	658 [390]	0.41
V (Special)	752 [445]	0.37**
V	752 [445]	0.37**
VI	752 [445]	0.37

*The Engineer will calculate water cement ratio (W/C) based on the total cementitious material including microsilica, fly ash or slag.

**When the use of microsilica is required as a pozzolan, the Engineer will approve mix designs at a maximum water cement ratio of 0.35.

346-4.2 Chloride Content Limits for Concrete Construction:

346-4.2.1 Genera: Use the following maximum chloride content limits for the concrete application shown:

Application	Maximum Allowable Chloride Content lb/yd ³ [kg/m ³]	
	Production	Mix Design
Non Reinforced Concrete	N/A	N/A
Reinforced Concrete that does not require Type II cement plus slag or pozzolan(s)	0.70 [0.42]	0.64 [0.38]
All applications that require Type II cement plus pozzolan(s)	0.40 [0.24]	0.34 [0.20]
Prestressed Concrete	0.40 [0.24]	0.34 [0.20]

Determine the chloride content as the average of three tests on samples taken from the concrete. Ensure that the range of results of the three tests does not exceed a chloride content of 0.08 lb/yd³ [0.05 kg/m³] of concrete. When test results are outside of the allowable range, run an additional three tests until the test results are within the allowable range. The Contractor may obtain samples from representative concrete cylinders or cores tested for compressive strength. If the cylinders or cores have been exposed to salt or aggressive environment, discard the outer 1 inch [25 mm] surface of the sample.

346-4.2.2 Sampling and Testing: Determine chloride content in accordance with FM 5-516.

(1) For all concrete requiring Type II cement with pozzolan(s) or slag and prestressed concrete, determine the chloride content on a frequency that is in accordance with these Specifications and the following procedures:

(a) When the chloride content is 0.25 lb/yd³ [0.15 kg/m³] or less, make subsequent tests on a frequency of not less than one for every four weeks of production as long as the test results remain at or below 0.25 lb/yd³ [0.15 kg/m³]. As an exception to the aforementioned testing frequency, when eight consecutive tests show chloride content below 0.25 lb/yd³ [0.15 kg/m³], the Engineer may reduce the frequency of testing.

(b) When the chloride content is greater than 0.25 [0.15] and less than or equal to 0.33 lb/yd³ [0.20 kg/m³], make subsequent tests at a frequency of not less than one for every two weeks of production, as long as the values remain at or below 0.33 lb/yd³ [0.20 kg/m³].

(c) When the chloride content is greater than 0.33 lb/yd³ [0.20 kg/m³], make subsequent chloride content tests for each day's production.

(2) For all reinforced concrete other than concrete requiring Type II cement with slag or pozzolan(s) and prestressed concrete, determine the chloride content on a frequency of not less than

one test every four weeks. As an exception to the aforementioned testing frequency, when eight consecutive chloride content determinations are below 0.40 lb/yd³ [0.24 kg/m³] of concrete, the Engineer may reduce the frequency of testing.

For any case listed above, when the source of any concrete component material, including admixtures, is changed, determine the chloride content immediately.

Test results obtained at the frequency provided above represent the chloride content of all concrete placed subsequent to the preceding test for the determination of chloride content.

346-4.2.3 Certification: Determine the chloride content, and certify the test results of chloride determinations to the Department. Include in the certification all pertinent data required by the Department. The Department will require properly executed certifications showing the chloride content within the required limits for acceptance of all concrete produced in accordance with these Specifications.

346-4.2.4 Control Level for Corrective Action: If the test results indicate that the chloride level is greater than the following limits, suspend concrete production until implementing corrective measures.

(1) Chloride content of 0.65 lb/yd³ [0.39 kg/m³] or greater for reinforced concrete that does not require Type II cement plus slag or pozzolan(s).

(2) Chloride content of 0.35 lb/yd³ [0.21 kg/m³] or greater for prestressed concrete and all applications that require Type II cement with slag or pozzolan(s).

The Engineer will reject the concrete exceeding the maximum allowable chloride content limits shown in 346-4.2.1, if an analysis by the Department indicates an unacceptable loss of concrete durability considering the environmental classification of the site.

346-5 Sampling and Testing Methods.

Perform concrete sampling and testing in accordance with the following standard Florida Test Methods:

Description	Method
Slump	FM 1-T 119
Air Content*	
Pressure Type meter	FM 1-T 152
Volumetric Type meter	FM 1-T 196
Chace	FM 1-T 199
Making and Curing Test Cylinders**	FM 1-T 023
Testing Cylinders**	FM 1-T 022
Taking and Testing Drilled Core Samples	FM 1-T 024
Early sampling of fresh concrete from revolving drum truck mixers or agitators	FM 5-501
Low Levels of Chloride in Concrete and Raw Materials	FM 5-516
Yield Test	FM 1-T 121
Temperature	ASTM C 1064
Sampling Fresh Cement Concrete	FM 1-T 141
Time of Setting of Concrete Mixtures by Penetration Resistance	FM 1-T 197
*Use the same type of meter for Quality Control tests as the Department uses for Quality Assurance testing. Where selecting pressure type meters, use an aggregate correction factor determined by the concrete producer for each mix design to be tested. Record and certify test results for correction factors for each type of aggregate at the plant. Use the Chace Air Indicator method for estimates only, and not for acceptance measurements.	
**To determine when a precast member or a structure may be put into service, when a prestress force may be transferred, or when forms may be removed, use the results of a strength test which is the average of the compressive strengths of two test cylinders cast from concrete sampled from the LOT representing that member or structure. Cure the cylinders by methods identical to those used in curing the concrete member or structure.	

346-6 Control of Quality.

346-6.1 General: Use a concrete plant approved by the Department for all concrete produced for incorporation into the work. Control Concrete production to meet the following criteria:

(1) Ensure that the average of any three consecutive strength test results does not fall below the specified minimum strength.

(2) Ensure that no strength test result falls more than 500 psi [3 MPa] below the specified minimum strength.

If the Contractor fails to meet the above specified criteria, the Department will automatically void plant approval. To obtain plant re-approval, implement corrective actions as approved by the Engineer. The Engineer may allow the Contractor to continue any ongoing concrete placement being supplied from a plant for which approval is voided during the progress of that placement; but the Engineer will not accept concrete from an unapproved plant for any new placement.

If the Department withdraws plant approval during production for a construction project, the Contractor is solely responsible to (a) obtain another approved concrete plant to produce the concrete, or (b) await re-approval of the concrete plant, prior to any further production and placement of concrete on the construction project. The Engineer will not allow changes in Contract Time or completion dates. The Contractor shall bear all delay costs or other costs associated with plant approval or disapproval.

In addition to plant approval, the Contractor and the concrete supplier shall exercise two levels of concrete quality control.

Exercise the first level of quality control in accordance with the approved Level I Quality Control Plan requirements in the Standard Operating Procedures. Include in the Level I Quality Control Plan all control activities for the production of concrete and its transport to the point of delivery at the site.

Exercise the second level of concrete quality control in accordance with the approved Level II Quality Control Plan requirements in the Standard Operating Procedures. Include in the Level II Quality Control Plan the necessary requirements to control the quality of the concrete between the point of delivery at the site and the final placement location, and other requirements contained in the Standard Operating Procedures.

Produce all concrete in accordance with an approved Quality Control Plan (including Level I and Level II) that has been developed and implemented by the Contractor and the concrete supplier in accordance with the Department's Standard Operating Procedures. These procedures require, in addition to a written Quality Control Plan, certified personnel and assurances that materials, plant, production, delivery and use of concrete comply with this Section.

346-6.2 Concrete Design Mix: Furnish concrete in accordance with the following requirements or order the concrete from a plant approved by the Department which has approved mix designs.

Prior to production of any concrete, submit a proposed mix design to the Engineer. Make a separate submittal for each class of concrete and each particular combination of component materials to be used at trial mix temperatures of 70 to 85°F [20 to 30°C], and for hot weather mixes as described in 346-6.2(5) at a minimum temperature of 94°F [35°C]. Use only design mixes approved by the State Materials Office. The approved concrete mix design will remain in effect until a change is authorized in writing by the Engineer.

Include the following with the mix design submittal:

(1) The Department approved source identification number for coarse and fine aggregates, along with the size of coarse aggregate and target Fineness Modulus for fine aggregate. Identify other component materials by manufacturer, brand name, and type.

(2) The actual proportions of raw materials intended to be combined to produce the concrete.

(3) The following mix data:

(a) Historical data from a minimum of 15 consecutive Department acceptance tests of production concrete made in accordance with the proposed mix design that

demonstrates that the proposed mix has met all applicable plastic and hardened concrete specification criteria herein without failure. For drilled shaft concrete to be placed in (1) a wet shaft, or (2) a dry shaft requiring a temporary removable casing, provide acceptable slump loss test results. The Engineer will not approve hot weather mixes based on historical data. When required, establish the plant standard deviation and overdraft requirements as described below.

(b) Alternatively, test data from a single trial mix which demonstrates that concrete produced using the proposed mix, designated ingredients and designated water-cement ratio will have a slump within ± 0.5 inch [± 15 mm] of the target value (or for mixes utilizing HRWR, within ± 1 inch [± 25 mm] of the target value), air content of 2.5% to 5% and strength required to meet an overdraft which is the minimum required strength plus 1.6 standard deviations.

(4) The chloride content of the proposed design mix. The Engineer will not approve mix designs when the chloride content of the trial mix exceeds the limits shown in 346-4.2.1.

(5) For design mixes developed for use under hot weather concreting conditions:

(a) Hold the trial mix prepared at a minimum temperature of 94°F [34°C] in the mixer for 90 minutes after completion of initial mixing. The Engineer will not require extended mixing for precast/prestressed concrete when centrally mixed at the placement site.

On completion of the extended mixing period, ensure that the trial mix concrete has a slump within ± 0.75 inch [± 20 mm] of the target value (± 1 inch [± 25 mm] for mixes utilizing HRWR), and an air content between 2% and 5%.

Ensure that the mix temperature at the end of the extended mixing period is not less than 94°F [35°C].

During the extended mixing period, turn the drum intermittently for 30 seconds every five minutes. Cover the drum with wet burlap or an impermeable cover material during the rest periods.

At the end of the 90-minute period, remix the trial mix for a minimum of one minute and make a slump test to verify that the concrete is within the specified range for slump. If below the target range, the Contractor may adjust the slump by a water addition. After the water addition, remix the concrete for a minimum of two minutes.

The total water used in initial mixing and the final slump adjustment constitutes the design mix water content. Ensure that the total water content does not exceed the maximum water cement ratio of Table 346-3 for the respective class of concrete.

(b) Ensure that the heat of hydration of the cement does not exceed 80 cal/g [335 kJ/kg] at seven days measured as the average of three samples, and that no individual measurement exceeds 90 cal/g [375 kJ/kg].

Where fly ash is 18% or greater or slag is 50% or greater of the total cementitious material, ensure that the heat of hydration of the cement does not exceed 88 cal/g [370 kJ/kg] at seven days measured as the average of three samples, and ensure that no individual measurement exceeds 96 cal/g [400 kJ/kg].

Do not apply these requirements to Type III cement, as allowed in 346-2.2, when used for precast and prestressed superstructures; do not apply these requirements to cements used for steam cured concrete.

(c) Supplement standard curing practices with additional methods, supplies or equipment which further reduce moisture loss from exposed surfaces during the required 72-hour curing period. These methods may include but are not limited to the following examples:

(1) Continuous or intermittent regular water fogging.

(2) Insulated curing blankets approved by the Engineer.

(3) Curing compound applied at a rate of 1.25 times the minimum rate required in 400-16.1.2.

(6) For design mixes proposed for use in wet drilled shafts, demonstrate the additional requirements in 346-3.2.

Ensure that strength test data for establishing the standard deviation of the plant proposed for use represents concrete produced to meet the specified strength of the mix submitted for approval within 1,000 psi [7 MPa]. Ensure that the strength test data represents either a group of at least 30 consecutive tests or a statistical average for two groups totaling 30 or more tests. When the Engineer cannot determine the plant standard deviation from historical data, apply an overdesign requirement, based on a singular trial mix, that is the minimum required strength plus 1,200 psi [8 MPa] for minimum required concrete strengths of 5,000 psi [35 MPa] or less. For minimum required concrete strengths above 5,000 psi [35 MPa], apply an overdesign requirement that is the minimum required strength plus 1,400 psi [10 MPa].

Demonstrate the production and testing of the trial mix concrete in the presence of the Engineer. The Contractor may also demonstrate a proposed mix design at a water-cement ratio exceeding that proposed to meet the slump, air and strength requirements above (but not to exceed the maximum water-cement ratio in Table 3). The Engineer will allow the highest water-cement ratio so demonstrated to provide the required overdesign strength requirements as an adjustment during production to maintain both plastic property and strength requirements of delivered concrete.

Ensure that preparation and testing of the trial mixes is performed by a laboratory acceptable to the Engineer which (1) has been inspected by the CCRL on a regular basis, with all deficiencies corrected, and under the supervision of a Specialty Engineer, or (2) meets all the requirements of ASTM C 1077. The Engineer may give consideration to approval of laboratories operating under other independent inspection programs demonstrated to be equivalent to the programs recognized in (1) and (2) above. Ensure that the 28-day strength (or strength at any other designated age) of trial mixes meets the above stated overdesign requirements to ensure that concrete sampled and tested at the point of placement has a strength exceeding the specified minimum strength in Table 2.

Do not place concretes of different compositions such that the plastic concretes may combine, except where the plans require concrete both with and without microsilica or calcium nitrite in a continuous placement. Produce these concretes using two separate design mixes. Designate the mix with microsilica or calcium nitrite as the original mix, and the mix without microsilica or calcium nitrite as the redesigned mix. Ensure that both mixes contain the same cement, fly ash or slag, coarse and fine aggregates and compatible admixtures. Submit both mixes for approval as separate mix designs, both meeting all requirements of this Section. Ensure that the redesigned mix exhibits plastic and hardened qualities which are additionally approved by the Engineer as suitable for placement with the original mix. The Engineer will approve the redesigned mix for commingling with the original mix and for a specific project application only. Alternately, place a construction joint at the location of the change in concretes.

346-6.3 Delivery Certification: Furnish certification to the Department with each batch of concrete delivered before unloading at the site. Certification shall be in the form of a delivery ticket on which is printed, stamped or written the information required in the Standard Operating Procedures, Attachment E.

346-6.4 Tolerances: Meet the following tolerances from target values for plastic concrete properties specified in 346-3.1:

Property	Tolerance
Slump (Non-Drilled Shaft Concrete)	± 1.5 inch [± 40 mm]
Slump (Drilled Shaft Concrete)	± 1 inch [± 25 mm]
Air Content	As shown in the range in Table 2

The Engineer will reject concrete with slump exceeding the above tolerances or air content exceeding the ranges in Table 2. The Engineer will not allow concrete to remain in a transporting vehicle to reduce slump. Do not add water to concrete delivered to the site which is within the target range for slump (target value ± 0.75 inch [± 20 mm] for non-drilled shaft concrete and ± 1 inch [± 25 mm] for drilled

shaft concrete), except in accordance with the approved Level II Quality Control Plan as allowed in the Standard Operating Procedures.

If the slump of non-drilled shaft concrete varies from the target value in excess of 0.75 inch [20 mm] (1 inch [25 mm] for concrete containing HRWR), immediately adjust the concrete mixture to correct the slump of succeeding batches. For concrete used in slipforms, make adjustments when the slump exceeds the target value by 0.75 inch [20 mm] or is 1.5 inch [40 mm] below the target value. The Engineer will allow a reasonable time for adjustment, considering trucks already in route from the concrete plant. If the Contractor does not implement adjustments at the earliest possible time, the Engineer will reject the concrete and terminate further production until the Contractor makes corrections.

346-7 Concrete Plant Requirements.

346-7.1 General: Produce concrete at plants that qualify as approved sources in accordance with the Standard Operating Procedures for Quality Control of Concrete.

Use equipment for handling elements, mixing concrete, handling the mixed concrete, transporting and depositing the mixed concrete that has no detrimental effect on the hardened concrete. Do not use equipment with aluminum surfaces in physical contact with the elements of concrete or mixed product.

346-7.2 Measuring Materials:

346-7.2.1 Water: Measure water by volume or weight. Whichever method is used, construct the equipment so that the accuracy of measurement is not affected by variations in pressure in the water supply line. Use a meter or weighing device capable of being set to deliver the required quantity and to automatically cut off the flow when the required quantity has been discharged. Ensure that the measuring equipment has an accuracy, under all operating conditions, within 1% of the quantity of water required for the batch. Verify the accuracy of measuring devices at the request of the Department, or at least quarterly.

The Contractor may exceed design mix water-cement ratios at the job site only if the Engineer has verified each mix to meet the minimum overdesign compressive strength requirements specified herein at the higher water-cement ratio. Adjust the mix consistency at the job site, within the allowable limit for the addition of water, only upon initial arrival of the concrete to the job site, as shown in the Level II Quality Control Plan requirements in the Standard Operating Procedures, and not thereafter.

Adjust the weight of mixing water for a concrete mix containing the corrosion inhibitor admixture calcium nitrite to account for water in the calcium nitrite solution. For each gallon [liter] of calcium nitrite solution added to the concrete, deduct 0.84 gallon [0.84 liter] or 7.0 pounds [3.2 kg] of water from the weight of the mixing water.

346-7.2.2 Admixtures: Measure admixtures by weight or volume. Use measuring equipment that has an accuracy, under all operating conditions, within 3% of the quantity of admixture required for the batch. Measure microsilica slurry to an accuracy of 1%. Ensure that the admixture supplier certifies the accuracy of measuring devices. Measure each admixture separately, and add it to the mixing water in a separate sequence as the mixing water is introduced into the mix.

For the dispensing equipment for a corrosion inhibitor admixture calcium nitrite solution, meet the requirements for measuring water as stated in 346-7.2.1. Store the calcium nitrite solution (neutral set version) in a dark container to protect against photo degradation.

The Engineer may make exceptions to the above method of admixture addition if the Contractor achieves the desired goals of each admixture and does not sacrifice the accuracy of measurement.

346-7.2.3 Cement, Fly Ash, Slag, and Microsilica: Measure cement, fly ash, slag, and microsilica (excluding slurries) by weight within an accuracy of 1% of the required total amount, except that for concrete batches of 3 yd³ [3 m³] or less, the Engineer will allow accuracy of 2%. Weigh cement, fly ash, slag and microsilica separately from other materials. When weighing cement, fly ash, slag, and

microsilica in a cumulative weigh hopper, weigh the cement first. Measure microsilica slurry as an admixture.

If bag cement is permitted, proportion the batch to use only whole bags.

346-7.2.4 Fine and Coarse Aggregates: Measure aggregates by weight or volume within an accuracy of 1% of the required amount. Apply aggregate surface moisture corrections.

346-7.3 Batching Plants:

346-7.3.1 Bins: Provide bins of adequate capacity for the required concrete production. Support the bins upon a rigid framework founded upon a stable foundation capable of holding them in a safe and secure position. Design each compartment to discharge efficiently and freely into the weigh hopper. Provide positive means of control so that as the quantity desired in the weigh hopper is approached, the material can be added slowly and the addition of further material can be stopped precisely. Use a discharging mechanism that prevents loss of material when it is closed. Construct aggregate storage bins sufficiently tight to prevent leakage of material, and divide them into at least one compartment for the fine aggregate and one compartment for each size of coarse aggregate to be used. Provide compartment partitions that are sufficiently tight and high enough to prevent intermingling of the several materials. Construct leak-proof and moisture-proof cement bins, and provide them with vibrators or other means to aid the flow of cement from the bin.

346-7.3.2 Weigh Hoppers: Provide weigh hoppers consisting of suitable containers freely suspended from scales and protected from the elements so that accuracy is not adversely affected. Equip the hoppers with a discharge mechanism which prevents leakage or loss of material when closed. Vent hoppers to permit air to escape and equip them with vibrators or other equipment that ensures complete and efficient discharge of materials.

346-7.3.3 Scales: Provide either beam type or springless dial type scales, or electronic devices such as load cells, manufactured by a recognized scale manufacturer. Where using beam type scales, provide suitable means to hold poises securely in position after they are set. Keep scales clean and in good operating condition. Where necessary, provide the scale operator with an unobstructed view of all indicating devices and convenient access to all controls. Use graduated weigh beam or dials to permit reading to 0.1% of the capacity of the scales.

Prior to beginning any work, ensure that all scales and other weighing devices used in batching are checked for accuracy by a qualified representative of a scale company registered with the Bureau of Weights and Measures of the Florida Department of Agriculture.

Recheck scales once every three months or more often if deemed necessary by the Engineer. Check scales up to at least the maximum load normally handled on each respective scale.

Maintain cement scales, pozzolan scales, and coarse and fine aggregate scales to an accuracy of 0.5% of the maximum load normally handled.

Affix a certificate of inspection bearing the date of the certification and signed by the scale company representative to each weighing device. Make available at the plant a copy of the scale company's report corresponding with the current certificate of inspection showing the date of inspection, signature of the scale company representative, the observed scale deviations for the loads checked, and a statement that the scale meets the requirements of Chapter 531 of the Florida Statutes pertaining to specifications, tolerances and regulations, as administered by the Bureau of Weights and Measures of the Florida Department of Agriculture.

Calibrate the dispensing equipment for calcium nitrite quarterly.

346-7.4 Mixers:

346-7.4.1 General Requirements: Provide mixers of an approved type that are capable of combining the components of the concrete into a thoroughly mixed and uniform mass, free from balls or lumps of cementitious material, and that are capable of discharging the concrete with a satisfactory degree of uniformity.

346-7.4.2 Design: Use truck mixers of the inclined axis revolving drum type, or concrete plant central mixers of the non-tilting, tilting, vertical shaft or horizontal shaft types.

Make available at the batching plant at all times a copy of the manufacturer's design, showing dimensions and arrangement of blades. The Contractor may use mixers that have been altered from such design in respect to blade design and arrangement, or to drum volume, when recommended by the manufacturer and approved by the Engineer.

Ensure that metal rating plates are attached to each mixer specifying its mixing speed, agitating speed, rated capacity and unit serial number.

346-7.4.3 Truck Mixers: Use truck mixers with a drum that is actuated by a power source independent of the truck engine or by a suitable power take-off. Ensure that either system used provides control of the rotation of the drum within the limits specified on the manufacturer's rating plate, regardless of the speed of the truck. Use truck mixers of the revolving drum type that are equipped with a hatch in the periphery of the drum shell which permits access to the inside of the drum for inspection, cleaning and repair of the blades.

Use truck mixers equipped with revolution counters of an approved type and mounting, by which the number of revolutions of the drum may be readily verified.

Ensure that the water supply system mounted on truck mixers is equipped with a volumetric water gauge or approved water meter in operating condition. Calibrate water measuring devices on truck mixers or other water sources used for concrete water adjustments annually.

Where job site water additions are controlled by a truck mixer volumetric gauge, park truck mixers in a level condition during on-site water adjustments so that the gauge is indicating a specific tank volume before and after the concrete adjustment. When water additions exceed 4 gal/yd³ [20 L/m³] of concrete, ensure that the water measuring equipment has an accuracy of within 3% of the indicated quantity.

346-7.4.4 Timers: Use stationary type mixers equipped with an approved timing device which will automatically lock the discharge lever when the drum is charged and release it at the end of the mixing period. In the event of failure of the timing device, the Engineer may allow operations to continue. Do not extend such operations beyond the end of that working day.

346-7.4.5 Cleaning and Maintenance of Mixers: Repair or replace mixer blades of revolving drum type mixers when the radial height of the blade at the point of maximum drum diameter is less than 90% of the design radial height. Repair or adjust mixers of other designs per manufacturer's instructions. Resolve questions of performance through mixer uniformity tests as described in ASTM C 94.

346-7.5 Trucks for Transporting Wet Batches: The Contractor may transport wet batches of concrete in either agitating or nonagitating trucks. Provide nonagitating trucks with bodies that are smooth, mortar tight containers with round internal corners, and capable of discharging the concrete at a satisfactorily controlled rate without segregation. Provide covers for nonagitating trucks for protection from the elements.

346-8 Mixing and Delivering Concrete.

346-8.1 General Requirements: Operate truck mixers at mixing speeds of 6 to 18 rpm and agitating speeds of 2 to 6 rpm (of the drum). Operate concrete plant mixers at speeds per the manufacturer's design or recommendation. Do not allow the volume of material mixed per batch to exceed the manufacturer's rated mixing capacity.

346-8.2 Central Mixing: After all materials are in the mixer, mix the concrete a minimum of two minutes or the manufacturer's recommended minimum, whichever is longer, unless a reduced mixing time is authorized by the Department. Mix concrete containing microsilica in accordance with the microsilica supplier's recommendations.

346-8.3 Transit Mixing: Initially mix each batch between 70 and 100 revolutions of the drum at mixing speed. When water is added at the job site, mix the concrete 30 additional mixing revolutions. When mixing for the purpose of adjusting consistency, do not allow the total number of revolutions at mixing speed to exceed 160. Discharge all concrete from truck mixers before total drum revolutions exceed 300.

Do not haul concrete in mixer trucks loaded with more than the rated capacity shown on their attached plates.

346-8.4 Mixing at the Site: For mixing concrete at the job site, use a mixer of sufficient capacity to prevent delays that may be detrimental to the quality of the work. Ensure that the accuracy of batching equipment is in accordance with requirements of this Section.

346-8.5 Charging the Mixer: Charge each batch into the drum so that some water enters both in advance of and after the cementitious material and aggregates. If using fly ash in the mix, charge it into the drum over approximately the same interval as the cement. Introduce microsilica into the mixer in accordance with the microsilica supplier's recommendations. The Contractor may use other time intervals for the introduction of fly ash into the mix when the Contractor demonstrates, using test requirements specified in ASTM C 94, that he can achieve uniformity of the concrete mix.

For concrete mixes containing the corrosion inhibitor calcium nitrite, charge the batch materials into the mixer in a sequence recommended by the calcium nitrite supplier.

346-8.6 Concreting in Cold Weather: Do not mix concrete when the air temperature is below 45°F [7°C] and falling. The Contractor may mix and place concrete when the air temperature in the shade, and away from artificial heat, is above 40°F [4°C] and rising. Do not heat aggregates or use salts to reduce the freezing temperature. Protect the fresh concrete from freezing until the concrete reaches a minimum compressive strength of 1,500 psi [10 MPa]. Do not apply this requirement where concrete is to be heat cured.

346-8.7 Concreting in Hot Weather: Hot weather concreting is defined as the production, placing and curing of concrete when the concrete temperature at placing exceeds 85°F [30°C] but is less than 100°F [40°C].

Unless the specified hot weather concreting special measures are in effect, including a design mix complying with 346-6.2, the Engineer will reject concrete exceeding 85°F [30°C] at the time of placement. Regardless of special measures taken, the Engineer will reject concrete exceeding 100°F [40°C]. Predict the concrete temperatures at placement time and implement hot weather measures to avoid production shutdown.

When the corrosion inhibitor calcium nitrite is used in a hot weather concrete mix, use a water reducing retardant admixture (Type D) and a high range water reducing admixture (Type F), and place the concrete in the early morning or at night.

346-8.8 Transit Time: Ensure compliance with the following maximum allowable time between the initial introduction of water into the mix and depositing the concrete in place:

Non-Agitator Trucks	Agitator Trucks
45 minutes	60 minutes
75 minutes*	90 minutes*
* When a water reducing and retarding admixture (Type D or Type G) is used. All time limits are subject to the ability of the Contractor to properly place and consolidate the concrete. When unable to place and consolidate the concrete within the time limits specified above, reduce the time limits to those limits which will result in acceptable placement and consolidation.	

346-9 Plastic Concrete Verification Sampling and Testing.

The Department will make initial verification tests on a sample from the initial delivery of each class of concrete to the job site each day to ensure compliance with the requirements in this Section for air content, temperature and slump. Furnish the Engineer sufficient concrete of each design mix as required by the Engineer for verification testing. Do not proceed with the placement operation until the delivered concrete complies with the specified tolerances in this Section for the plastic concrete. The Engineer will reject non-complying loads which cannot be adjusted at the job site in accordance with 346-6.4 and the Standard Operating Procedures. Ensure that corrections are made by the concrete producer on subsequent loads.

After the Contractor begins concrete placement, the Department will make intermediate verification tests, as determined necessary by the Engineer, to ensure compliance with specification requirements for concrete plastic properties. The Engineer will reject non-complying loads which cannot be adjusted at the job site in accordance with 346-6.4 and the Standard Operating Procedures.

If the Engineer obtains an intermediate verification test failure of a load of concrete before any concrete from that load is placed, the Engineer will reject the load. Continue placement operations with the next load that is in compliance with requirements for air content, temperature and slump. The Engineer will not terminate the LOT.

If the Engineer obtains an intermediate verification test failure of a load of concrete that has been partially placed, The Engineer will reject the remainder of that load and terminate the LOT. The Engineer will make acceptance cylinders representing that LOT from the same sample of concrete unless acceptance cylinders have previously been made representing that LOT.

Following termination of a LOT, the Engineer will re-initiate initial verification tests until such time as the air content, temperature and slump comply with specification requirements. The Engineer will initiate a new LOT once the testing indicates compliance with specification requirements.

When three consecutive LOTs, or when five LOTs in two days of production of the same design mix are outside the specified tolerances, suspend production. Make the necessary revisions to concrete operations or the Quality Control Plan to bring the concrete within allowable tolerances. Obtain the Engineer's approval of the revisions prior to resuming production.

346-10 Acceptance Sampling and Testing.

346-10.1 General: The Department will make acceptance testing on samples of the concrete delivered to the job site. Furnish the Engineer sufficient concrete of each design mix as required by the Engineer for acceptance testing.

Furnish and maintain, throughout the required curing period, facilities suitable for curing concrete test cylinders in accordance with the requirements of FM 1-T 023 including power supply, equipment and materials necessary for proper operation.

346-10.2 Sampling Frequency for Acceptance Tests: The Engineer will randomly sample and test concrete for each design mix for air content, temperature, slump and compressive strength in accordance with the following schedules as a minimum. The Engineer will select acceptance samples from each LOT on a random basis to represent the entire LOT of concrete. The Engineer may perform additional sampling and testing to satisfy the Department's Material Sampling, Testing and Reporting Guide requirements. If the Contractor stops concrete placement for more than 90 minutes, the Engineer will initiate a new LOT when the Contractor restarts concrete placement. The Engineer will terminate a LOT when any acceptance test fails.

Class Concrete	Maximum LOT Size
I (Pavement)	1 mile [1.5 km] or 1/2 day's production, whichever is less
I (Special)	150 yd ³ [125 m ³] or one day's production, whichever is less
II, II (Bridge Deck), III, IV, IV (Drilled Shaft), V (Special), V, VI	50 yd ³ [40 m ³], or one day's production, whichever is less
III (Seal)	Each Seal placement

346-10.3 Strength Test Definition: The Department will determine a strength test for a LOT as the average of the compressive strengths of two test cylinders cast from a sample of concrete from the LOT, except that if one test cylinder shows evidence of improper sampling, molding, handling, curing or

testing, the Engineer will disregard that cylinder and the Department will determine the compressive strength value for the LOT as the test result of the remaining cylinder.

346-10.4 Acceptance of Hardened Concrete: The Engineer will accept (or reject) hardened concrete on the basis of strength test results as defined in 346-10.3. The Engineer will not discard a cylinder strength test result based on low strength (strength below the specified minimum strength as per the provisions of 346-3 and 346-10). The Engineer will accept at full pay only LOTs of concrete represented by strength test results which equal or exceed the respective specified minimum strength. The Department will obtain strength test results at the frequency specified in 346-10.2.

346-11 Investigation of Low Strength Concrete for Structural Adequacy.

346-11.1 General: When a concrete acceptance strength test result falls more than 10% or 500 psi [3.5 MPa] below the specified minimum strength, whichever is the lesser deviation from the specified minimum strength, and when the Department determines that an investigation is necessary, the Department will make an investigation into the structural adequacy of the LOT of concrete represented by that strength test result.

346-11.2 Determination of Structural Adequacy: When the Department determines a need to investigate structural adequacy, perform a structural analysis as shown in (b) below or take drilled core samples to determine the in-place strength of the LOT of concrete in question. If the Contractor takes cores, both the Contractor and the Department shall accept the core strength test results obtained as the in-place strength of the LOT of concrete in question. These core strength test results will be final and used in lieu of the cylinder strength test results for determination of structural adequacy.

If drilled cores are taken and the core strength test results are less than 10% below the specified minimum strength, and this deviation from the specified minimum strength does not exceed 500 psi [3.5 MPa], consider the concrete represented by the cores structurally adequate. If the core strength test results are more than 10% or 500 psi [3.5 MPa] below the specified minimum strength, whichever is the lesser deviation from the specified minimum strength, the Department will consider the concrete represented by the cores structurally questionable. Then the Contractor may either:

(a) Remove and replace the LOT of concrete in question at no additional expense to the Department, or

(b) Submit a structural analysis performed by a Specialty Engineer. If the results of the analysis, approved by the Department, indicate adequate strength to serve its intended purpose with adequate durability, the Contractor may leave the concrete in place. Otherwise, remove and replace the LOT of concrete in question at no additional expense to the Department.

The Engineer may accept low strength concrete at reduced payment in accordance with the provisions of 346-12.

346-11.3 Coring for Determination of Structural Adequacy: If the Contractor uses core samples from the hardened concrete to determine structural adequacy, the Contractor shall obtain the cores and repair the core holes. Drill the cores at the same approximate locations from which the test cylinder concrete was obtained, as approved by the Engineer. Select the location of the drilled cores so that the structure is not impaired and does not sustain permanent damage after repairing the core holes. When the Contractor supplies drilled core samples, the Engineer will require three undamaged samples. The Engineer will not accept cores taken without Department approval.

346-11.4 Core Conditioning and Testing: If the Contractor provides drilled core samples for determination of structural adequacy, the Department will test the cores in accordance with FM 1-T 024. The Department will immerse the cores in water for at least 40 hours, and test the cores wet.

346-11.5 Core Strength Representing In-Place Concrete Strength: The Department will consider the core strength obtained as the in-place concrete strength for structural determinations of the LOT of concrete in question. The Department will calculate the strength value to be the average of the compressive strengths of the three individual cores. The Department will accept this strength at its actual measured value, as determined by FM 1-T 024.

346-12 Pay Adjustments for Low Strength Concrete.

346-12.1 General: The Engineer may accept any LOT of concrete failing to meet the specified minimum strength as defined in 346-3, 346-10 and 346-11 when the Department determines that the concrete has been adequately consolidated, cured, and satisfactorily meets all other requirements of the Contract Documents, including structural adequacy. The Engineer will individually reduce in price, in accordance with 346-12, any LOT of low strength concrete accepted.

346-12.2 Basis for Pay Adjustments: When a concrete acceptance strength test result falls more than 10% or 500 psi [3.5 MPa] below the specified minimum strength, whichever is the lesser deviation from the specified minimum strength, the Contractor may elect to drill core samples from the respective LOT of concrete represented by the low acceptance strength test result for determining pay adjustments.

When cores are not taken, the Engineer will determine payment reductions based upon the results of strength tests performed on acceptance sample cylinders required in accordance with 346-10.

When the Contractor elects to supply drilled cores and submits acceptable drilled core samples to the Engineer for testing, the Engineer will determine payment reductions based upon the results of strength tests performed on those cores. Both the Contractor and the Department shall accept the results of strength tests of the drilled cores, subject to 346-12.5 and 346-12.6, as final and in lieu of the cylinder strength test results for determining pay adjustments.

Do not core hardened concrete for determining pay adjustments when the 28-day acceptance cylinder strength test results are less than 10% below the specified minimum strength, and this deviation from the specified minimum strength does not exceed 500 psi [3.5 MPa].

346-12.3 Coring for Determination of Pay Adjustments: If the Contractor elects to drill core samples from the hardened concrete for determination of pay adjustments, obtain the cores in accordance with 346-11.3.

346-12.4 Core Conditioning and Testing: If the Contractor elects to provide drilled core samples for determination of pay adjustments, the Department will test the cores in accordance with 346-11.4.

346-12.5 Core Strength Representing Equivalent 28-Day Strength: For cores tested no later than 42 days after the concrete was cast, the Engineer will accept the core strengths obtained as representing the equivalent 28-day strength of the LOT of concrete in question. The Department will calculate the strength value to be the average of the compressive strengths of the three individual cores. The Department will accept this strength at its actual measured value, as determined by FM 1-T 024.

346-12.6 Core Strength Adjustments: For cores tested later than 42 days after the concrete was cast, the Department will establish the equivalency between 28-day strength and strength at ages after 42 days based on test data developed by a Department approved testing laboratory to relate strength at the actual test age to 28-day strength for the particular class of concrete and design mix represented by the cores. Obtain such data at no additional expense to the Department. When such data is not available and cannot be produced, as determined by the Department, the Department will determine the equivalent 28-day strength by adjusting the tested core strengths according to the following relationship:

$$\text{Equivalent 28-Day Strength} = \frac{\text{Average Core Strength} \times 100}{F}$$

where:

$$\begin{aligned} F &= 4.4 + 39.1 (\ln x) - 3.1 (\ln x)^2 && \text{(Type I Cement)} \\ F &= -17.8 + 46.3 (\ln x) - 3.3 (\ln x)^2 && \text{(Type II Cement)} \\ F &= 48.5 + 19.4 (\ln x) - 1.4 (\ln x)^2 && \text{(Type III Cement)} \\ x &= \text{number of days since the concrete was placed} \\ \ln &= \text{natural log} \end{aligned}$$

346-12.7 Calculating Pay Adjustments: The Engineer will determine payment reductions for low strength concrete, accepted by the Department and represented by either cylinder or core strength test results below the specified minimum strength, in accordance with the following:

Reduction in Pay = \$0.80/yd³ [\$1.05/m³] for each 10 psi [70 kPa] of strength test value below the specified minimum strength.

The Engineer will denominate low strength concrete paid on a per foot [meter] basis in cubic yards [cubic meters] by multiplying the plan cross-section of the element incorporating the low strength concrete by the full length of that element, or by 150 feet [45 m], whichever is less.

The Engineer will apply a reduction in pay to the entire LOT of concrete represented by the low strength test results except as noted above for concrete paid on a per foot [meter] basis, where the amount might exceed one LOT.